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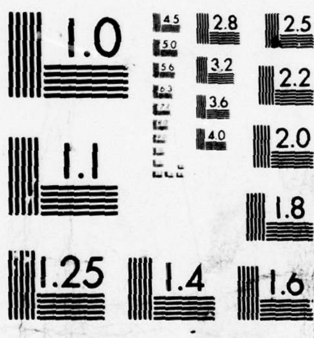
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REPORT DELNV-TR-0008

REALISTIC EUROPEAN BATTLEFIELD TARGET ACQUISITION MODEL (REBTAM)

by
James A. Ratches

July 1979

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U.S. ARMY ELECTRONICS R&D COMMAND
NIGHT VISION & ELECTRO-OPTICS LABORATORIES
FT. BELVOIR, VIRGINIA 22060

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

REBTAM is a developmental model which relates tactical and meteorological parameters directly to sensor performance. Major subroutines consider the impact of target signatures, natural and battlefield atmospheric propagation, and line-of-sight limitations. REBTAM can generate sensor performance profiles which quantify the effectiveness of an electro-optical (E-O) sensor averaged over the historic distribution of observed weather data in any geographic location.

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ILLUSTRATIONS

REALISTIC EUROPEAN BATTLEFIELD TARGET ACQUISITION MODEL (REBTAM)

I. FORMALISM

The continuous land combat of a European battlefield in the 1980's will be radically different from any previous conflict. Not only will there be increased firepower and mobility compared to the past, but the actual fire control and weapons delivery will be significantly more sophisticated. These systems will be automated, computerized, and sometimes, smart, and they will rely heavily on sensors for reconnaissance, surveillance, and target acquisition. Even in the target-rich environments of a midintensity European war, sensors will be used to set priorities for targets, to track targets, and to penetrate battlefield obscurants. After the ordnance has been delivered, sensors will be used for second-round correction or damage assessment. The sensors will be so critical to fire control systems that sensor limitations will be the overall weapons systems limitations. The primary limitations of electro-optical sensors on the battlefield are environmental in nature; e.g., target strength, atmospheric propagation, and terrain limitations. The quantification of these environmental effects and their frequency of occurrence on the battlefield as they determine sensor performance is the rationale for REBTAM.

The Realistic European Battlefield Target Acquisition Model is a program at the Night Vision and Electro-Optics Laboratory (NV&EOL) to quantitatively assess the impact of environmental conditions on electro-optical sensor performance for a European battlefield. REBTAM is designed to relate environmental observables to sensor performance. In this way, the user in the field can determine friendly and threat sensor capabilities without taxing his support and logistics to conduct scientific experiments directed at more directly meaningful physical parameters which determine environmental impacts. Hence, the starting point for the REBTAM is the tactical scenario.

Tactical scenario (Figure 1) means gross tactical observables such as geographic location. threat force structure, type of munitions expended, etc. The geographic location (e.g., Germany) implies a corresponding distribution of weather and terrain conditions that are indigenous to such a location. The force structure identifies the threat targets and vehicles which generate the proper target signature for the climatological conditions occurring. The munitions expended determine the extent of battlefield obscuration due to manmade sources such as artillery-delivered smoke, smoke generators, artillery barrage dust, and vehicular dust. These inputs plus terrain descriptors are usually obtained through intelligent preparation of the battlefield and together they drive the three submodules shown in Figure 1.

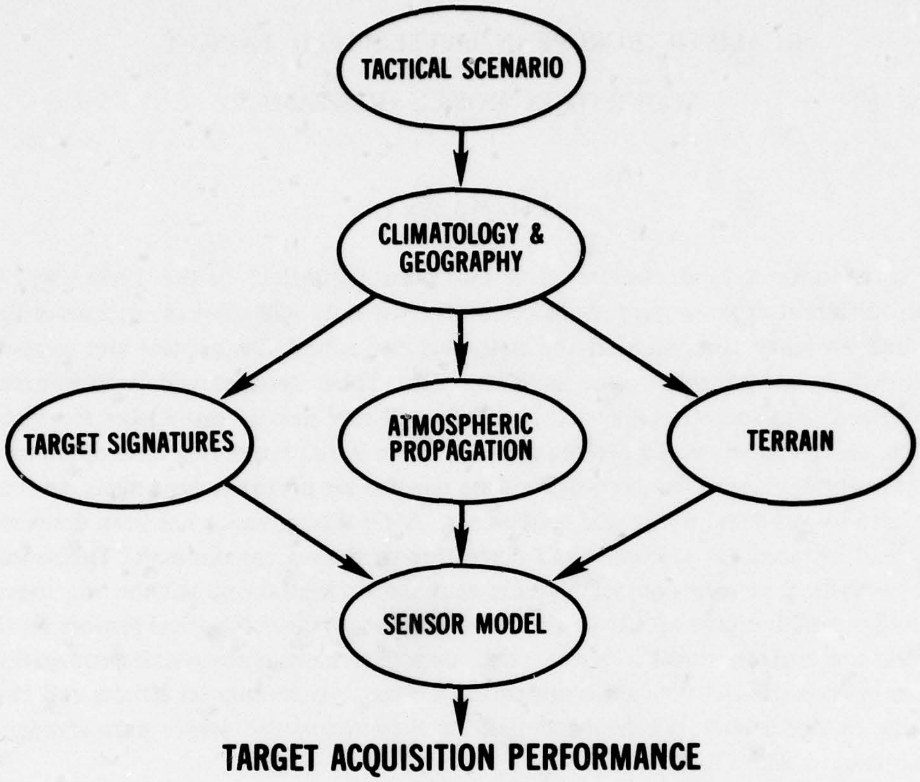

Figure 1. European Battlefield Target Acquisition Model (REBTAM).

The first of these modules is the target signature subroutine. Presently this consists of a matrix of most probable signatures in each spectral region for each important target such as M-60, XM-1, T-62, T-72, M113, BMP, BRDM, ZSU-23, etc. There is a value for each vehicle of different signature strengths corresponding to the diurnal, seasonal, aspect, and environmental variation. This module will eventually be replaced by a more first-principle-oriented, empirically based model E-O SIGMO (Signature Model) which will have the ability to predict signatures as a function of environmental variables.

The second of the environmental modules of REBTAM is the atmospheric propagation subroutine. This consists of a set of models and scaling laws relating transmission in each spectral band to precipitable water and visibility for natural degradation, concentration of smoke, soil content, and number of rounds of high explosive (HE) artillery munitions. Rudimentary relationships for smoke and dust cloud transport and diffusion based on data from several recent smoke and artillery barrage dust

field trials [1 2 3 4 5] are also available. As in the case of the target signature module, this atmospheric routine will eventually be replaced by the more analytical model E-O SAEL (Sensor Atmospheric Effects Library) being developed by the USA Atmospheric Sciences Laboratory (ASL).

The last environmental module is the terrain routine being driven primarily by the geographic location of the battle. This subroutine would consist of data bases of line-of-sight (LOS) distributions obtained at the various locations. These distributions are still in the process of being identified, since the pertinent data bases must consider threat avenues of approach. Many LOS distributions do not take into account that the attacker cannot approach along any route but only along relatively high trafficability avenues. This consideration can increase the LOS probability significantly over the more conventional distributions which consider any direction equally probable.

The outputs from these three routines are target-to-background signal strength, atmospheric transmission, and probability of line-of-sight. These outputs are the inputs to the sensor performance models which predict target acquisition probability as a function of range or time for the given inputs. This kind of calculation is called a real-time calculation, since a calculation is made for a given set of instantaneous target signature, atmospheric propagation, and LOS conditions.

The true uniqueness of REBTAM is in the historic mode calculation. In this mode the sensor model is run iteratively for a distribution of signature, atmospheric, and terrain values based on the climatology distribution for the desired geographic location. In this way a distribution of performance is generated for the distribution of environmental conditions observed at the location. Such a distribution of performance is called a sensor performance profile.

An example of a sensor performance profile for a hypothetical infrared night sight is shown in Figure 2 for Grafenwoehr, Germany during 0600 to 1200 hours of September to November. The vertical axis is the cumulative frequency of occurrence of performance shown along the horizontal axis. This axis represents increasing task difficulty; e.g., classification, recognition, and identification (or number of resolvable

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1 "Manportable Common Thermal Night Sight Smoke Test at White Sands Missile Range – July 1977 (U)," PM SMK-T-001-78 Jan 78 (Confidential), DDC No. ADCO 15243.

2 Metz, Dolce, "An Analysis of Smoke Cloud Data from Aug 75 JPG Smoke Test." AMSAA TR201, Sep 77.

3 "Smoke Week I, Electro-Optical (E-O) Systems Performance in Characterized Smoke Environment at Dugway Proving Ground, UT – Nov 77 (U)." DRCPM-SMK-T-002-78, Apr 78 (Confidential), DDC No. ADCO 15328.

4 Unpublished Smoke Week II Field Test results at Eglin AFB, Florida; sponsored by PM Smoke/Obscurants; Nov 78.

5 Unpublished GRAF II Field Trials results conducted by NV&EOL in Grafenwoehr, Germany; Nov 78.

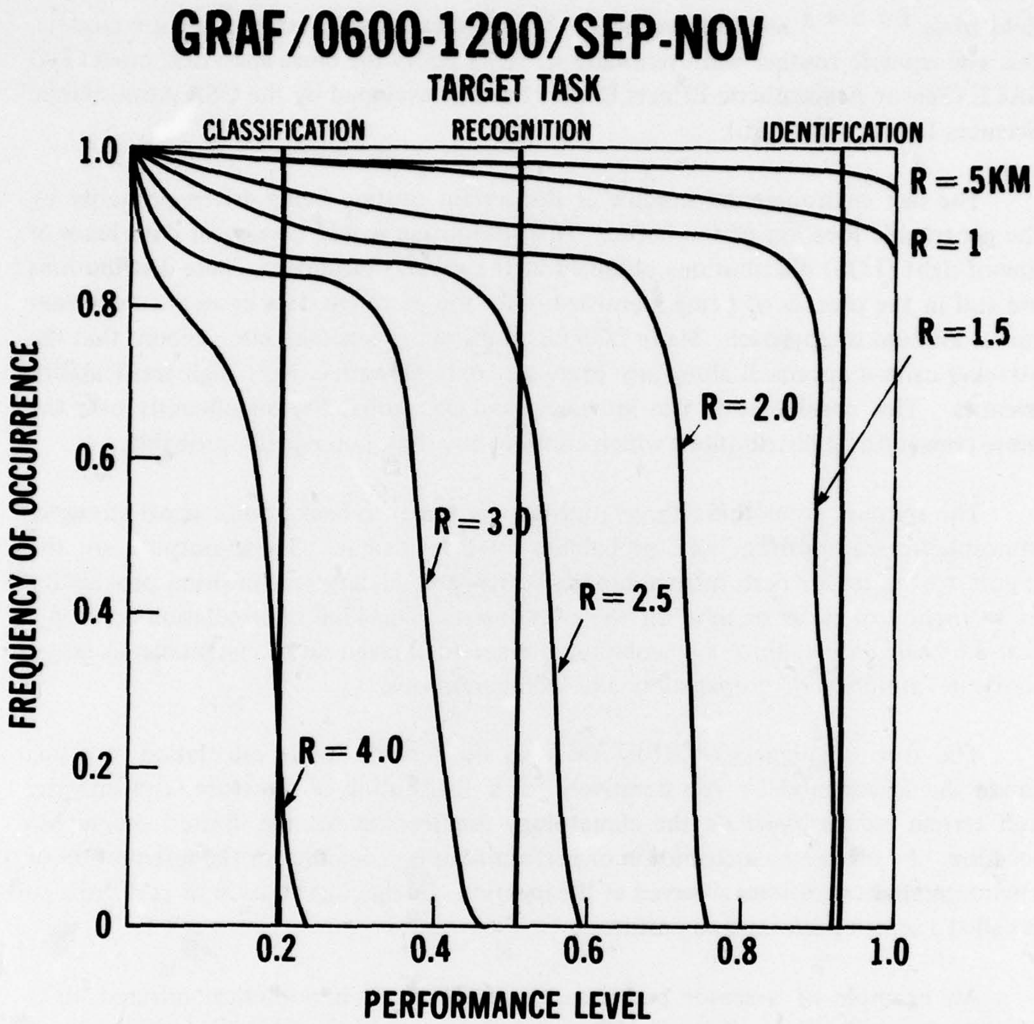

Figure 2. An example of a sensor performance profile for a hypothetical infrared night sight.

cycles required across the target). The curves are parametric in range R between observer and a tank target. Figure 2 was calculated considering only a distribution of recorded natural atmospheric conditions for one tank temperature difference and assuming LOS. This figure shows, for example, that the natural atmospheric conditions in Grafenwoehr allow recognition of a tank to occur at 2 kilometers approximately 90 percent of the time.

The importance of such historic mode calculations can be realized by considering that they tell the user of this sensor how often he can meet his specification level of performance at the location. Usually the specification level of performance is based on the level of performance required to carry out a certain military mission. Hence, an

historic mode calculation specifies the percent of time a user can expect to accomplish his mission with the device, given the distribution of naturally occurring atmospheric conditions.

The outputs of the sensor model for real time or historic mode can then be input to a one-on-one engagement model which, in turn, would feed a force-on-force simulation. Work is planned to incorporate a tracking/homing module into REBTAM in order to simulate the "end game" and make it a self-contained one-on-one simulation. Presently, the sensor model outputs are fed directly into force-on-force simulations.

II. RATIONALE

There are several important points on REBTAM that need be emphasized. The first is that REBTAM generates a distribution of transmission over a time slice based on hourly sampled meteorological data. That is, transmission in the infrared is based on simultaneous humidity, air temperature, and visibility observations. It is incorrect, as Huschke[6] has pointed out, that a distribution of each met variable cannot be convolved to generate the representative IR transmission distribution, since the three met variables are not independent. Hence, transmission must be calculated point by point in time before a representative distribution can be generated. Note, however, that even when this is done, the resulting distribution can vary depending how the time intervals for sampling are chosen. Figure 3 shows the result of lumping data hourly or over 6 hours. The 0600 to 1200 curve in Figure 3 is the same as the 3-km curve of Figure 2. The other curves represent the sensor performance profiles generated for individual hourly samples of simultaneous meteorological (met) data.

The second important point to be stressed about REBTAM is the interaction between signatures and weather conditions. It is critical to realistic performance profiles that the weather conditions be the driving function for the selection of target signature strength. Precipitation, solar insolation, and air temperature can be three of the most important determiners of temperature difference in the infrared after the operational status of the target; i.e., static or active.

The third point to be made about the rationale for REBTAM is that terrain limitations must be included in any realistic assessment of sensor operational capability. It is obvious that a sight designed to see "half way around the world" would be of dubious utility for a tank sight in Central Europe. Figure 4 shows the effect of a typical distribution of LOS for various heights, h, above average terrain level. Again the $h = \infty$ curve is the 3-km curve of Figure 1. It can be seen that the realistic con-

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[6] R. E. Huschke, "Atmospheric Visual and Infrared Transmission Deduced from Surface Weather Observations: Weather and Warplanes VI." Rand R-2016-PR, Oct 76.

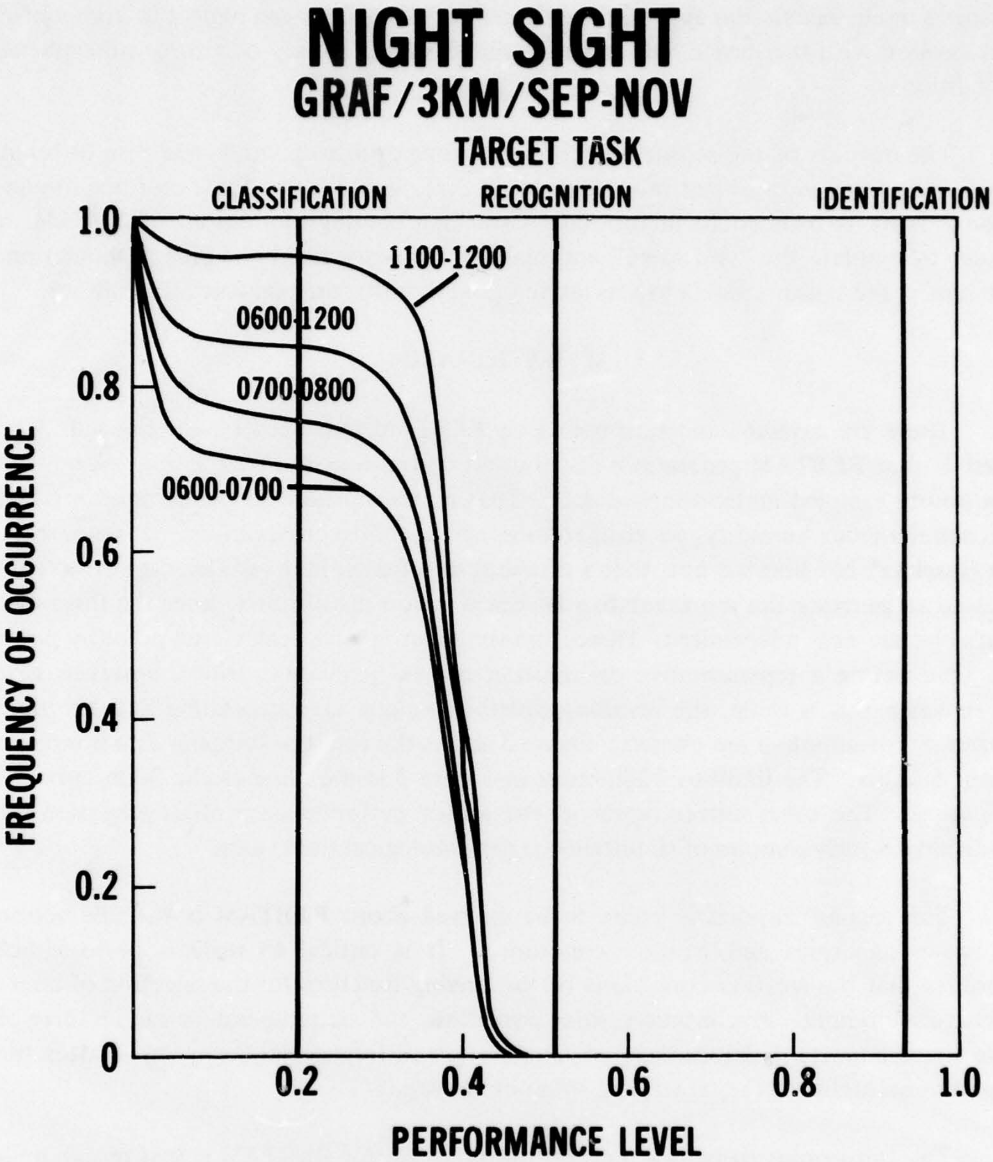

Figure 3. The result of lumping data hourly or over 6 hours.

sideration of terrain limitation can be the absolute driving force to sensor performance under certain conditions.

LOS also can be the driving function in sensor design optimization. System design trade-offs between sensitivity and resolution should be made in favor of sensitivity when LOS is the limiting factor in sensor performance range. By designing for

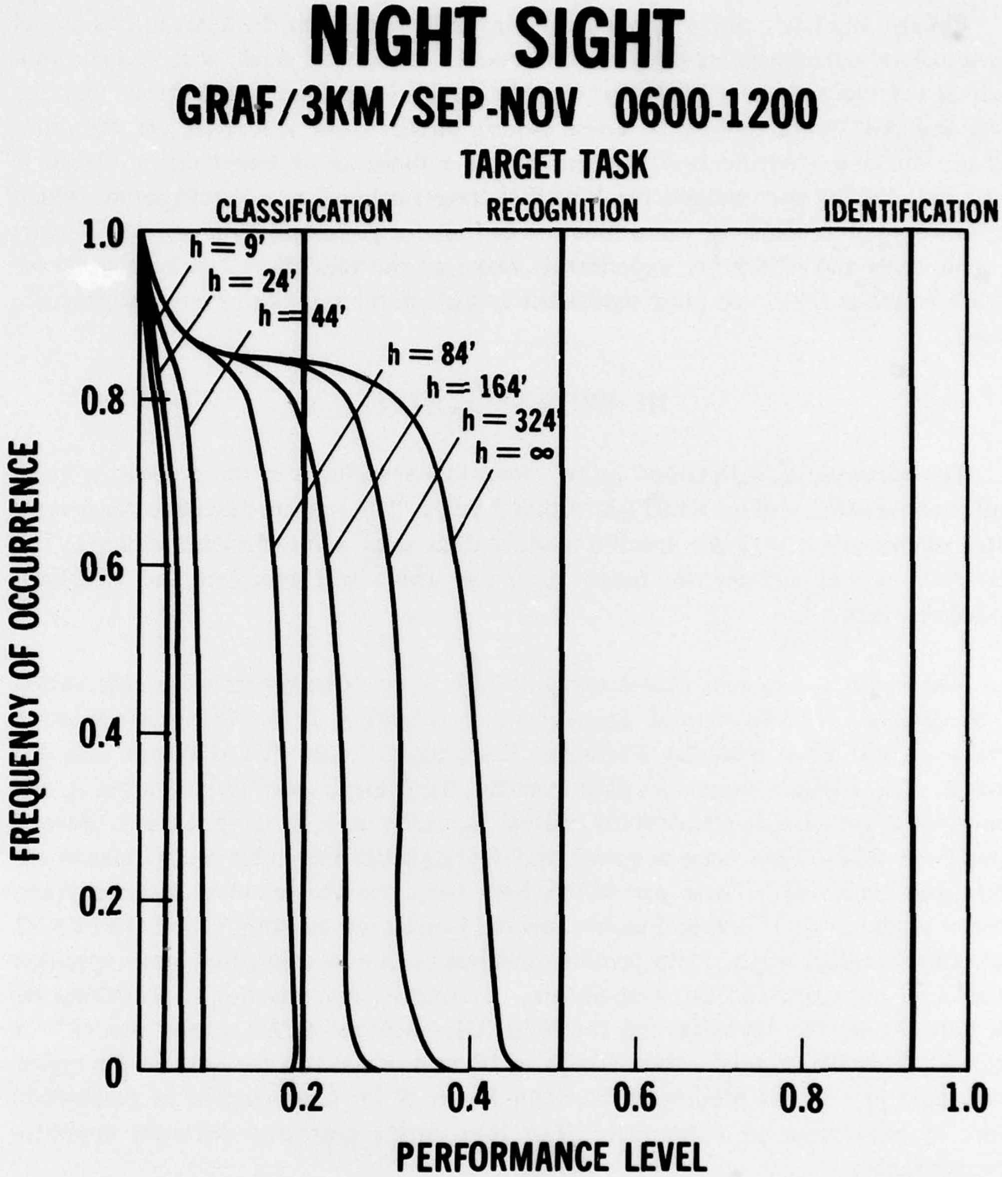

Figure 4. The effect of a typical distribution of LOS for various heights above average terrain level.

sensitivity, for example, in a tank fire control sight, the LOS ranges can be realized under all atmospheric degradations. Conversely, a design trade-off for an airborne sight can be made to a certain degree in favor of higher resolution since the altitude associated with the aircraft implies longer LOS and less of a limitation on performance range. Hence, performance under optimum visibility can be improved through increased sensor resolution.

Finally, the last point to be made about REBTAM is that the heart of this model is a set of validated systems performance models. The most widely accepted and validated is the thermal viewing systems model,[7] which is routinely used throughout the DOD and NATO communities. These models predict static detection, classification, recognition, and identification performance as a function of target range. Work is being initiated to also include the NV&EOL target acquisition (search) model which predicts detection probability as a function of time for given target ranges. Many years of field trials and laboratory experiments make up the validation data base for these models which is the single most significant consideration in choosing any performance model.

III. PRESENT STATUS

The methodology described in the preceding sections is in the process of being implemented into a full up REBTAM within 2 years. This section describes the present status of this effort with the specific models, data bases, and techniques utilized. The next section will address the future direction which will complete the REBTAM modeling effort.

The weather data base that is being utilized in order to generate the distribution of transmission due to natural atmospheric propagation is the USAF Air Weather Service (AWS) Environmental Technical Assessment Center (ETAC) data base for Europe. The critical observables used from this data base are visibility, dew point, and dew-point depression (equivalent to relative humidity and air temperature). Several tapes from ETAC have been acquired and the statistics for Fulda and Grafenwoehr have been generated. These parameters have been used to calculate infrared transmission in the 8- to 12-μm and visible spectral bands hour by hour. The LOWTRAN[8] atmospheric model was used to predict transmission due to absorption losses specified by relative humidity and air temperature. Transmission losses due to scattering are calculated using the visibility and the NV&EOL-developed G/AP aerosol model.[9] A result of the generation of a distribution of IR transmission in the 8- to 12-μm region from these inputs and models is shown in Figure 5 for Grafenwoehr at 0600-1200 hours in September to November. The four curves represent different target-to-observer ranges.

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7 Ratches, Lawson, Obert, Bergemann, Cassidy, and Swenson; "Night Vision Laboratory Static Performance Model for Thermal Viewing Systems." USA Electronics Command Rpt. ECOM-7043; Apr 75; AD-A011212.

8 R. A. McClatchey, R. W. Fenn, J. E. A. Selby, F. E. Volz, and J. S. Garing; "Optical Properties of the Atmosphere." Air Force Cambridge Research Lab; Cambridge, Massachussetts; 1971, DDC No. AD726-116.

9 F. Shields, "NV&EOL G/AP Aerosol Atmospheric Models." NV&EOL internal memorandum, Sep 78.

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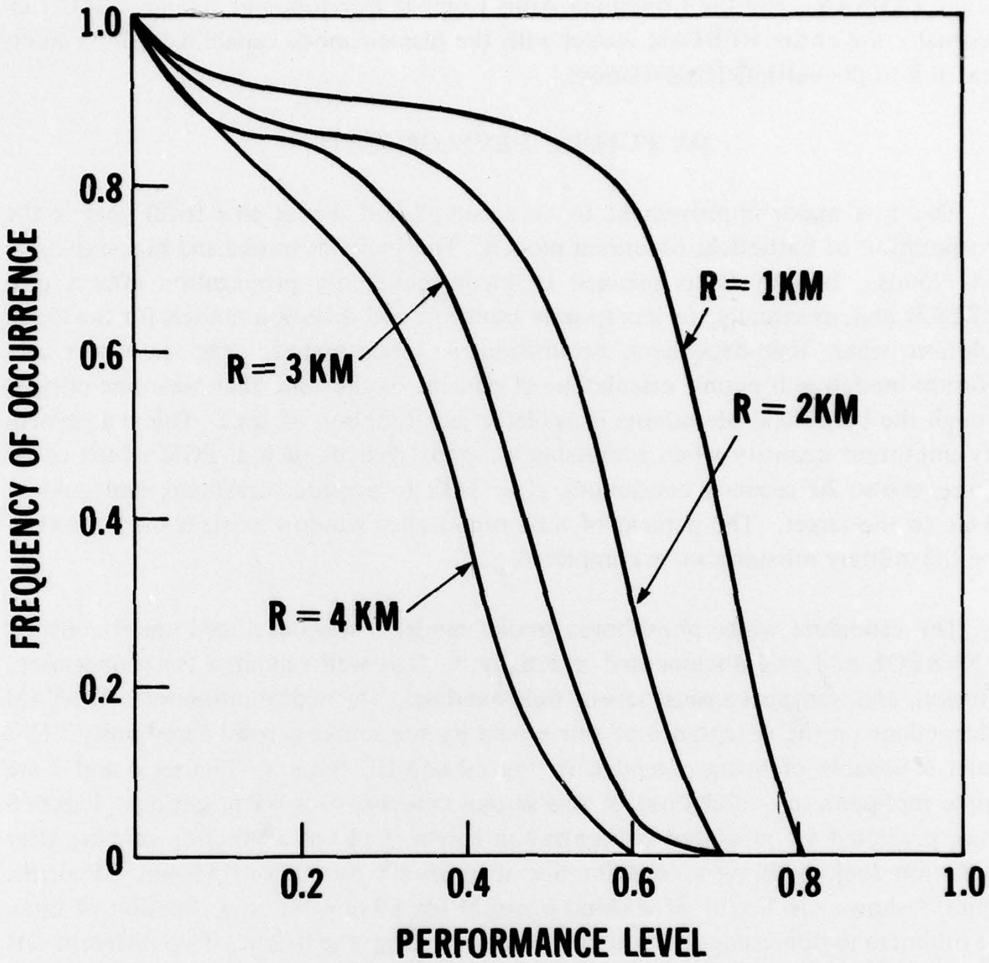

Figure 5. Infrared transmission in the 8- to 12-μm band.

At present, battlefield obscurants and target signature scaling laws have not been incorporated in REBTAM. These items will be addressed in the next section.

The present performance models that can be addressed are visual (direct view), image intensifier, TV, and thermal imaging. Sensor performance profiles can be generated for these devices similar to the figures already shown. The methodology for

calculation is given by Moulton et al.[10] [11] Real time outputs from these models have been used as inputs directly to force-on-force simulations at Concepts Analysis Agency (CAA), TRADOC Analysis Agency (TRASANA), Army Materiel Systems Analysis Agency (AMSAA), and the Combined Arms Combat Development Agency (CACDA). Eventually the entire REBTAM model with the historic mode capability will be incorporated into the battlefield simulations.

IV. FUTURE DEVELOPMENTS

The first major improvement to be accomplished during this fiscal year is the incorporation of battlefield obscurant models. This includes smoke and high-explosive dust clouds. Initially, it is planned to incorporate only propagation effects into REBTAM and, eventually, to incorporate transport and diffusion models for the cloud evolution when time-dependent acquisition is incorporated. The transport and diffusion models will permit calculation of percent of the time that clear line-of-sight through the battlefield obscurants is available as a function of time. This is a particularly important quantity when addressing weapons systems such as PGM which could require about 20 seconds continuous clear LOS to acquire, designate, and guide a missile to the target. The percent of time such a clear window exists is the percent of time the military mission can be completed.

The candidate white phosphorus smoke model[12] was developed under contract to NV&EOL and was documented internally.[13] It is well validated for propagation, diffusion, and transport against several field exercises. Its incorporation into REBTAM is dependent on the acceptance of this model by the smoke aerosol community. This model is capable of being extended to fog oil and HC smokes. Figures 6 and 7 are sample representative validations of this smoke model against WP munitions. Figure 6 shows predicted vs. measured concentration length (CxL) as a function of time after detonation looking along a constant line through six rounds of 155-mm WP shells. Figure 7 shows the height of a cloud centroid for 60-mm WP as a function of time. The other cloud dimensions are directly obtainable from the height. Two different sets of curves show the effect of including or excluding the heat generated from the exothermic reaction in the smoke cloud and the resulting convection currents.

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[10] J. R. Moulton, J. A. Ratches, and A. Linz; "Operational Effectiveness of Electro-Optical Sensors (U)." 26th National IRIS; U.S. Air Force Academy, Colorado; May 78 (Confidential).

[11] Moulton, Shields, Ratches, and Cassidy; "E-O Target Acquisition Sensor Performance in Central Europe (U)." IRIS Specialty Group on Imaging; Naval Academy, Annapolis, Maryland; Jun 78 (Confidential).

[12] R. Zirkind, "An Obscuring Aerosol Dispersion Model." Vols. I and II, final rpt. CR-231 for U.S. Army NV&EOL under contract DAAK02-74-C-0366 by General Research Corp.; McLean, Virginia; Dec 78.

[13] Unpublished NV&EOL report on validation and user's guide for NV&EOL/GRC smoke model.

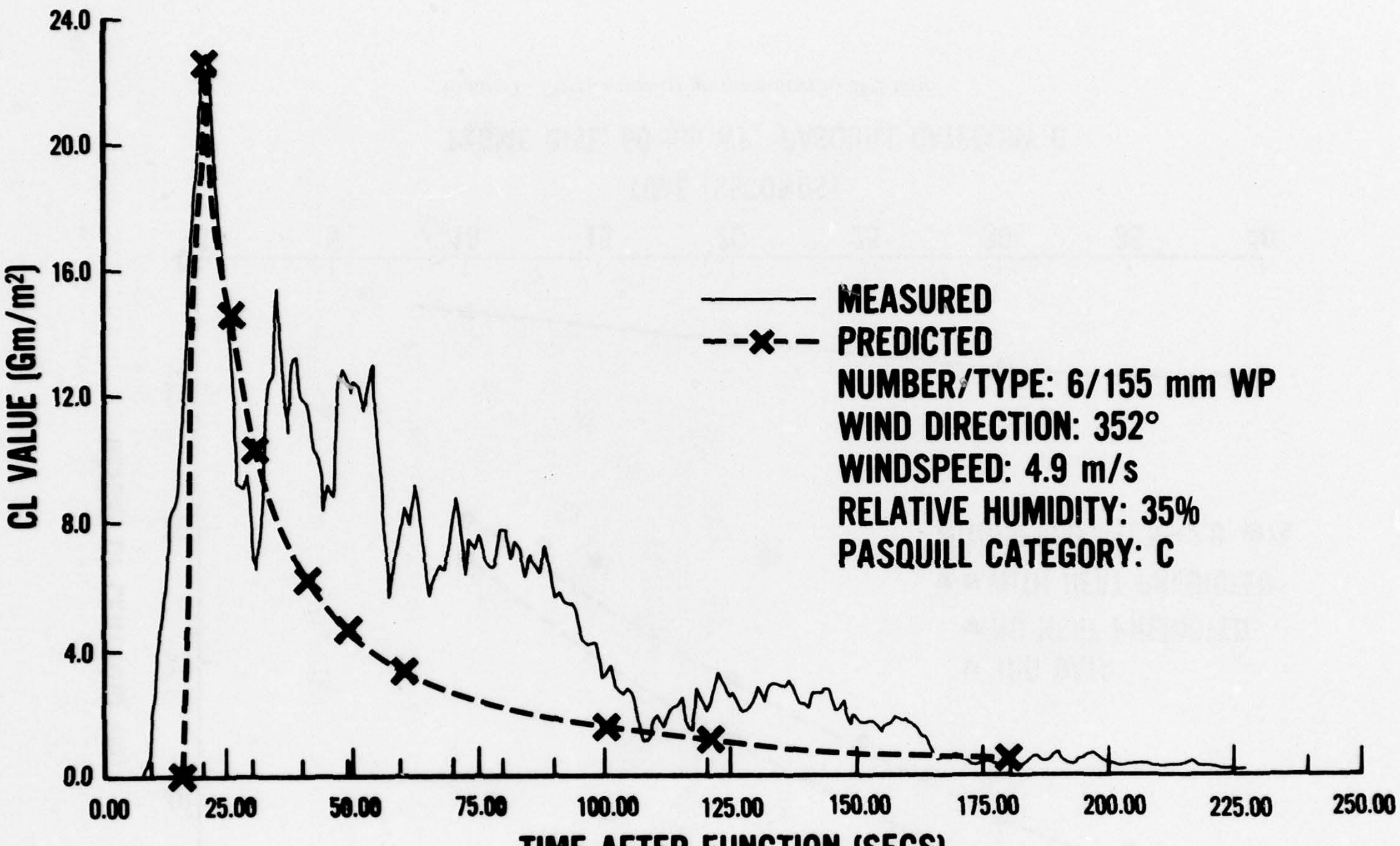

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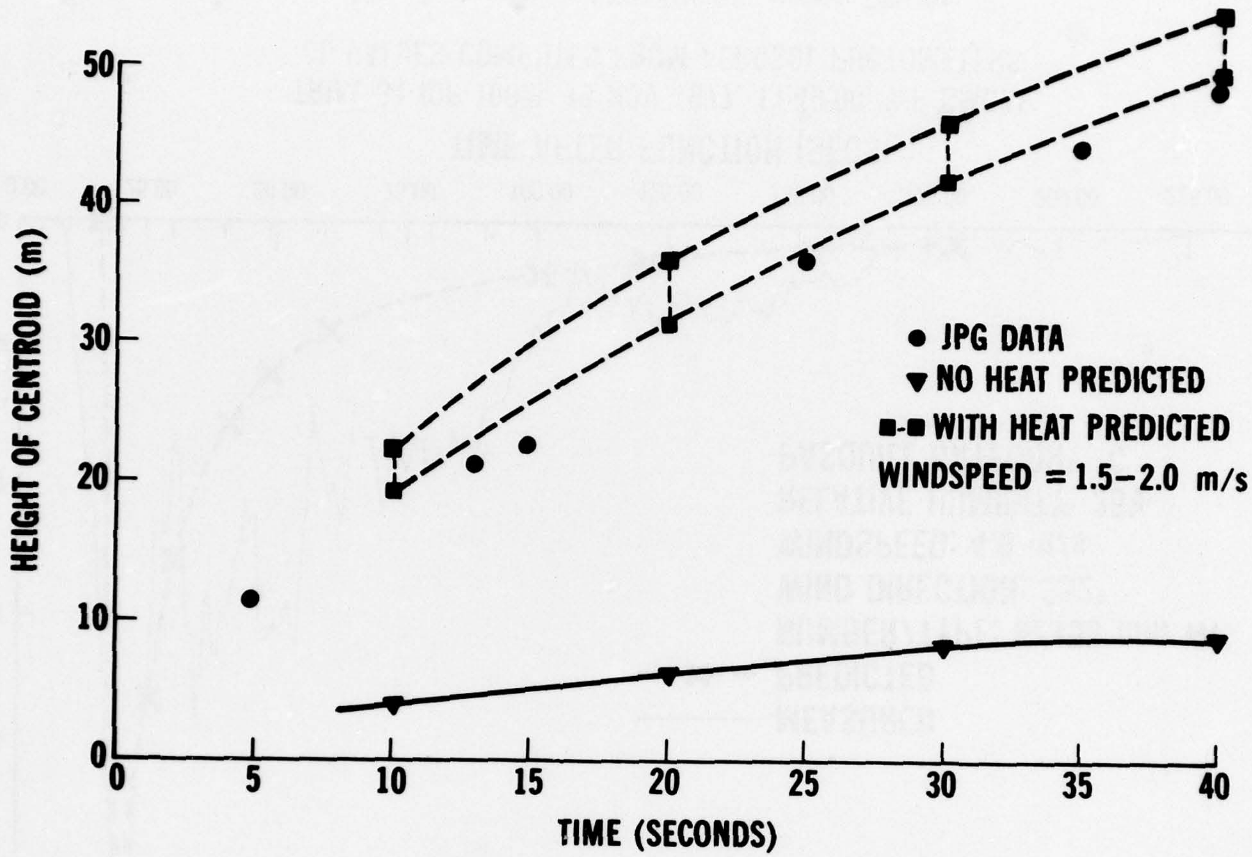
Figure 6. Comparison of NV&EOL/GRC model to DPG data.



PLUME RISE, 60 mm WP, PASQUILL CATEGORY B

Figure 7. Comparison of plume model to JPG data.

A battlefield dust model due to artillery barrages also has been developed under contract.[14] The data collected at the NV&EOL GRAF II field trials will be used as the main validation for this or any other dust model the community finally accepts. The selected dust model will be the one incorporated in REBTAM.

Another major milestone in the REBTAM development is the inclusion of target signature scaling laws which relate target-to-background strength to meteorological conditions. In the visible region this would be contrast; in the infrared, temperature differences; and in the mm region, reflectances. These quantities must be related empirically to solar insolation, time of day, season, precipitation, past history, operational condition, etc. Work on this model has begun under contract and internally.

The performance models which are the core of REBTAM are planned to be extended to laser active systems and mm wave radar. Because of new emphasis in the Army to use 10.6-μm laser to overcome obscurant limitations and mm waves to augment FLIRS for all weather capability, the need for REBTAM to address these sensors is obvious.

Finally, realistic line-of-sight distributions need to be established. The need for terrain limitations which consider avenues of approach has already been addressed in a previous section. The literature must be thoroughly searched to come up with the required distributions for the major geographic locations.

V. MILESTONES

With the recent completion of the GRAF II winter trials and the planned GRAF II follow-on summer trials, validation for HE dust models should be available in sufficient quantity. It is reasonable to expect that a validated dust and smoke model should be incorporated into REBTAM this fiscal year. Contractual and internal efforts should also conclude the development of first-order target signature scaling laws by the end of the year.

A user-oriented handbook of sensor target acquisition performance for natural environments will be generated this year. This handbook will tabularize the sensor performance profiles similar to Figure 1 for deployed sensors of the U.S. Army. Systems will include manportable, vehicle, missile, and airborne devices operating in the visible, near IR, far IR, and mm wave regions. Central European sites will be selected, and seasonal and diurnal time slices will be chosen for graphical representation. The frequency of occurrence for detection and recognition will be chosen as the figures of

[14] R. Zirkind, "A Preliminary Description of an Explosive Dust Cloud Model." TM-235 prepared for NV&EOL under contract DAAK02-74-C-0366 by General Research Corp.; McLean, Virginia; Dec 78.

merit for these sensors. A later version of the handbook will show the effects of smoke concentration and dust obscuration as a function of number of rounds or pots or generators under the various environmental conditions.

Finally, a series of sensitivity analyses will be carried out during the next few years to determine the critical values of met parameters in relation to sensor target acquisition performance. These analyses will be performed for two different communities; TRADOC and the atmospheric measurement community. Sensitivity analyses directed towards TRADOC[15] will show the critical values of the met parameters where device performance is seriously impacted. This information will be used to design tactics, determine mix and basis of issue for sensors, and determine the battlefield met support required to the field commander. The atmospheric measurement community needs to be directed as to the ranges of met parameters that need be emphasized in experimentation and the dependence of the sensor performance on choice of atmospheric transmission model and uncertainty in met values. The met parameters that have the greatest influence on transmission and sensor performance must be determined so that the major variances in atmospheric models can be resolved.

VI. CONCLUSIONS

The Realistic European Target Acquisition Model is a performance model for E-O sensors on the modern battlefield. REBTAM includes in one formalism the effects and the distributions of natural atmospheres, target signatures, battlefield obscurants, and terrain limitations. It relies solely on tactical inputs, and its output can be used for design and R&D investment decisions by commodity developers, optimization of tactics and doctrine by the TRADOC community, and determination of military worth by the force-on-force simulation community.

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[15] Letter from TRADOC HQ; Fort Monroe, Virginia; subj: Realistic Meteorological Conditions for Electro-Optical Sensor/Weapon Systems, 8 Dec 78.

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1	Commander Anniston Army Depot Anniston, AL 36201
1	Dept of Defense Production Engineering Spt Ofc (PESO) ATTN: H. K. MacKechnie Cameron Station Alexandria, VA 22314